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ABSTRACT

In human communication research today, two fundamental issues must be addressed. The first issue concerns the need for study of communicative relationships as events that change over time. The second issue involves the nature of the data currently gathered in such research and its adequacy in providing information concerning change. In order for research to reflect the nature of communication events as part of a larger, ongoing process, three criteria must be met: measurement of the variables under study and concurrent measurement of the points at which such variables occur must be made, at least three observation points must be included within the design, and measurement must be continued throughout the interval of concern or over a subinterval if variation is periodic or cyclic. While researchers must explore and adopt techniques to index change over time, they must also fully exploit more familiar techniques, as well as develop new methods. (KS)

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Studying Ongoing Human Communicative Relationships: Criteria for Indexing Change over Time

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Prologue

Imagine for a moment an empirical researcher who is engaged in building a theory of human communication which focuses on individuals as they function in relationship to one another. Imagine further that this researcher is seated in a laboratory located in a windowless ivory tower. In place of windows, the lab is equipped with a large screen on which the researcher may observe any desired communication event, life-size, in color, and with three-dimensions, sound, odor, etc. The lab is also equipped with sophisticated apparatus to make and record measurements of any variables the researcher wishes to study.

At the moment the researcher is ready, the screen flashes a view of a particular communication event, and after a fraction of a second goes blank again. The researcher then begins to analyze the data that were recorded as the screen flashed, and in so doing produces evidence from which he or she draws theoretical interpretations about the event observed. Once these steps are complete, the researcher prepares to study another communication event.

"A ridiculous image!" you retort. "How could one possibly build a theory of human communication from research which looked at many different events, each for an instant of time? Even if one had all the necessary instrumentation, the results wouldn't tell much about what goes on in communication because most of the important information would be missing!"

Imagine then, as an alternative, that the same researcher, in the same ivory tower laboratory, programs the screen and the recording equipment for a new mode

of operation. Now, when all is ready, the screen flashes for an instant with a new communication event, and then goes blank while the event continues. After several moments, the screen flashes again with another, later scene from the same event. The researcher then utilizes the two sets of data in the analysis, and makes interpretations based on the evidence of differences between them.

"A definite improvement," you reply. "A series of studies like this might produce some basic theory about what goes on when people communicate. There's more information available about the changes which occur in the events. But there still wouldn't be enough information to really get at the heart of how those changes occur in communication."

Imagine then, one final alternative. The researcher modifies the apparatus to present a rapid sequence of scenes from a single, ongoing communication event. Indeed, the screen now flashes (and the data are recorded) so frequently that the pauses seem hardly noticeable, and it continues to do so until the researcher determines that enough data are available. He or she then draws on all sets of data in an analysis which produces evidence for theoretical interpretations regarding changes in the event over time.

"There'd be more data than anyone could handle!" you respond once more. "Yet conducting a number of studies of this sort could be a big step toward a theory which explains how communication grows or dies between people. In fact, there'd be enough information in studies like this that they might become a window on what human communication is all about...."

The Problem

Its imaginary nature aside, for the moment, the "prologue" serves as a stepping stone for considering two issues which underlie the concerns of this paper. One issue is the position that ongoing human communicative relationships need to be studied as events which change over time. The other involves the nature of the data gathered in much human communication research today, and

its adequacy in providing information on change over time. A brief consideration of these two issues will lead to the basic conerns of the paper: to provide criteria for indexing change over time, and to examine what these criteria imply for the study of human communication.

There is, first of all, an "intuitive" basis for the position that the communication which occurs in ongoing human relationships needs to be studied in a manner which provides information on how such events change over time. This intuitive basis underlies the prologue, but needs some clarification. To look at any on-going event using the prologue's first paradigm is equivalent to taking a snapshot of it. The measurement procedures used in actual research take more time than the brief "flash" suggested above, but formally many research designs reduce to a recording of the state of an event at a particular point in time. Research involving such "point" designs is of definite value, just as are individual photographs, but there is both a quantitative and qualitative advantage to approaching an ongoing event as in the second paradigm--a parallel to the familiar "before and after" photographs.

Data from two points in time separated by some interval permit identification of differences that may have developed--an important form of information which point designs cannot provide. But despite their value, "difference" designs are also limited, for they cannot produce information on the pattern or the form of the change in the event which produced the overall difference. Research which studies an ongoing event as in the prologue's third paradigm can provide this information, for it is analogous to taking a motion picture of the occurrence. Intuitively, the presence of data from a large number of points within an interval seems most satisfactory, for it allows one to deal with the fundamental concerns of change over time or process. "Change over time" or "process" designs thus appear crucial if one seeks information on how on-going human communicative relationships are initiated, maintained, and

perhaps terminated.

But beyond this intuitive rationale, there is a second, firmer basis for maintaining that the communication in ongoing relationships needs to be studied as it changes over time. This basis stems from the growing awareness of the need to approach human communication utilizing the perspectives of general systems theory. Arguments for adopting systems concepts in communication research are relatively frequent, and there is space here to do no more than characterize them (see Arundale, 1968; Fisher and Hawes, 1971; Krippendorff, 1971; Monge, 1972 and 1973; Rubin, 1972; Rubin and Kim, 1975; and more generally, Laszlo, 1972). Rubin (1972, p. 120), for example, notes that:

> For those interested in human communication, a general systems approach has much to offer. It presents a way of thinking about living things--as living systems--and focuses attention on the fundamental life processes that all living things have in common: the metabolism of matter-energy and the metabolism of information. From this perspective, communication is basic to the activity of all living things, and therefore central to the emergence and survival--the total functioning--of human beings, their friendships, families, organizations, and societies.

And Monge (1973, p. 16) closes his argument for a system paradigm in communication theory building with the comment that:

> I believe that the adoption of this theoretical strategy will cause us to focus on a new set of variables and employ a new set of analytic techniques which will significantly increase the ability of communication scientists to understand, predict, control, and explain the phenomenon of communication.

In order for communication scholars to move beyond such arguments and begin to incorporate general systems approaches in their research, they will have to make some changes. Specifically, they will have to add to their present techniques new tools for gathering information relevant to a number of basic systems concepts, among which are the concepts of "structure" and "process" in events. These are not the only systems concepts which future research must consider, but they are fundamental, as a study of almost any general systems theorist will suggest (e.g., Bertalanffy, 1968, Ch. 3; Laszlo, 1972, Ch. 5; J.G. Miller, 1965a, pp. 209-211, and 1965b; Rappoport, 1968).[1] J.G. Miller,

in fact, defines "structure" in terms of "process": "All change over time of matter-energy or information in a system is process (1965a, p. 209)," while "Structure is the static arrangement of a system's parts at a moment in three-dimensional space (1965a, p. 211)." Process, or change over time, is thus one key concept which must be indexed in research on ongoing human communicative relationships, if that research is to make meaningful use of general systems approaches.

The "idea of process" was current in discussions of human communication well before arguments for adopting a general systems approach began to appear. Berlo's 1960 treatment of the concept is frequently cited (pp. 23-28), although there have been many other calls to focus on this concept (Chronkite, 1969, pp. 131-133; Kibler & Barker, 1969, p. 35; Krippendorff, 1970, pp. 258-267; Scheidel, 1971 and 1972; and Smith, 1972, among others). A critical study of the use of the term "process" in such discussions reveals a much broader, more inclusive meaning than J.G. Miller's definition as "...change over time...." Indeed Berlo's treatment, which was clear and concise for its day, can now be seen to encompass not only change over time, but also concepts such as irreversibility, continuity, interrelatedness, relativity, equifinality (or multicausality), interaction, emergence, and complexity (Arundale, 1973, pp. 1-5). Yet among these meanings encompassed in the broader use of the term "process," "change over time" stands out as most important (Arundale, 1971, pp. 28-32, and 1973, pp. 6-8; cf. Kress, 1970, pp. 189-193, and Scheidel, 1971, p. 6). The many calls to study the process of communication may thus be seen as calls to study change over time in communication, together with a number of other important attributes of ongoing events. Given that all of these concepts are important ones in general systems theory, one wonders in retrospect if the earlier focus on communication as a process was not also an early argument for what amounted to a "general systems approach" to human communication.

These earlier calls to focus on "process" in its broad sense, together with the recent arguments for a general systems approach, suggest strongly that human communication events need to be studied in terms of change over time, or in terms of "process" in its narrow sense. Human communication theory would remain stifled if process or change over time were the only systems concept which researchers operationalized: adequate studies must also provide information on other systemic properties such as interaction and emergence. Change over time is the concept of primary concern in this paper because of its importance in both systems theory and communication theory. But how does one determine whether or not the data gathered in a study of an ongoing communication event are in fact "adequate" to provide information on change over time?

Considering the issue of the adequacy of some set of data requires a brief look at the nature of data in empirical research in general. In his continuing study of such data, Coombs (1953; cf. 1964) has noted that: "What one 'finds out' from one's data is a function of two things: the information the data contain and how this information is extracted. What information the data contain depends on how they are collected. Some methods of collecting data 'permit' more characteristics of behavior to exhibit themselves than do other methods (p. 471)," and later: "The method of collecting data determines what information they contain, but the method of analysis defines this information (p. 495)." Krippendorff (1970, pp. 242-243) has incorporated Coomb's position in his discussion of four basic steps in scientific inquiry: (1) The scientist selects or decides on the observations to be made; (2) the observations are formalized or "identified, labeled, classified, measured, or 'translated' into terms amenable to subsequent analysis (p. 242)," resulting in data, per se; (3) the data are subjected to analytic procedures which produce evidence of relations and structures in the data; and finally, (4) the scientist produces a theoretical interpretation of the evidence by assigning meanings to its terms or outputs.

These basic steps in "generating data" and "producing knowledge" are evident in the prologue. What may not be evident, as Coombs and Krippendorff point out, is that the decisions and assumptions made in generating the data will restrict the information they contain, and will make them formally incapable of producing certain kinds of evidence for use in theoretical interpretation. Because of the data gathering procedures involved, the first and second paradigms in the prologue (point and difference designs) are formally incapable of generating data and hence evidence that can be interpreted in terms of "change over time," or "process" in its narrow sense.[2] Only research such as that in the third paradigm can produce the necessary data, and given the appropriate analysis techniques, the necessary evidence for theoretical interpretations in terms of "change over time." What is crucial in considering research on human communication is that the great bulk of empirical study falls into the first and second paradigms of the prologue in terms of design and type of data produced (see Arundale, 1971, pp. 55-74). The third paradigm is found in some communication research (as below), but for the most part it appears that past discussion or theoretical interpretation in terms of change over time in ongoing human communicative relationships has been based on information other than that contained in research data.[3]

It is important to note that in the above references, Krippendorff (1970) is concerned with what he terms "communication data," or in other words, data which provide, at minimum, "...evidence of the existence or nonexistence of communication processes (p. 246)." Formally, such data are "richer" in terms of the information they contain than the data on change over time considered here, because they must also contain information capable of supporting an interpretation in terms of the broader concept of "communication." Krippendorff recognizes that communication data must contain, among other things, information regarding "process" or "change over time" (1970, p. 245), but he does not specifically address the requirements which a research design must meet in order

to produce such data. It is the purpose of this paper both to provide criteria for designs that produce data which will index change over time, and to consider the implications of those criteria for the conduct of communication research. Again, the need for data on change over time can be seen "intuitively" as well as in both calls to utilize a systems perspective and injunctions to study communication as a process. Not all research into human communication needs to index change over time, for much has been learned already, but advancing the state of communication theory beyond its present point appears to require some additions to the types of research commonly encountered.

The Criteria

Several clarifications are needed before developing the three criteria. First, the concern in this paper will be entirely with communication variables whose "states" are capable of continuous measurement (interval or ratio level measurement). Such variables are fairly common in human communication research, as in studies of attitude or of credibility. Space precludes a treatment of discrete-state variables such as "category of interaction" or "leadership rank," even though such variables have an important place in communication research. Indeed, there appears to be little or no consideration of the problems of studying change over time in discrete-state variables in the literature of communications engineering and related fields. This literature is one of the bases for what follows, but is concerned entirely with continuous-state variables.

Second, this paper will focus entirely on cases where time is measured at the interval or the ratio level, as in normal "clock time." No consideration will be given to nominal or ordinal measurement of time, as in "before" and "after," or "trials 1,2, and 3." Note one important point, however, regarding the use of the terms "continuous" and "discrete" with reference to time in fields such as communications engineering. "Continuous time" is uniformly used to refer to the analog recording of time, while "discrete time" refers to

the recording of time (and of the value of a variable state) at each of a sequence of individual points in time (digital recording). References to "discrete time" in these contexts assume that the time points are spaced at equal intervals or are separated by intervals which are measured using a common metric. Hence "discrete time" in these fields virtually always assumes interval and usually ratio measurement of time, and is used primarily to refer to the recording of values at each of a series of separate points in time. This latter form of recording time is extremely frequent in communications engineering, and has an important place as well in human communication research. Indeed, even if analog recording were used, any analysis would probably employ a sequence of time points, for to do otherwise would require very specialized equipment for analog computation.[4]

Third, it will be most convenient in developing the criteria to consider only the state of a single variable as it changes over time. This focus on a single variable or "signal" (in the terminology of communications engineering) does not in any way preclude what follows from applying to cases where multiple variables or signals are involved. In these cases each signal would have to be measured in accord with the criteria to assure that the resulting data were an adequate index of the change over time in that variable. With this condition satisfied, there are a number of possible approaches to the analysis of multiple signals (Jenkins and Watts, 1968, Chs. 8,9, 11; Kendall, 1973, Ch. 10; Koopmans, 1974, Ch. 5; and Quenouille, 1957). The discussion to follow will also focus only on signals within some bounded interval of time (as opposed to the "infinite duration" signals sometimes assumed). Such a restriction has two advantages: (1) it relates what follows to the normal communication research situation where one always has only a finite-length data record, and (2) it allows extension of what follows to signals which are "non-stationary," or which have long term changes in mean and variance. Such signals are of interest

in communication research (e.g., one often expects long term changes in individuals), but could not be considered unless this restriction were made.[5]

Given these preliminary comments, the first of the three criteria which a research design must meet to produce data which index change over time should come as no surprise. The design must involve:

> (1) Measurement of the value (or state) of the variable(s) under study, and of the points in time at which such measurements are taken.

If the variable under study were measured at all points in time within the interval of concern (analog measurement of time) the data would fully index the change over time in the signal and no additional criteria would be necessary to judge the adequacy of the data. As suggested above, however, analog treatment of time is not especially frequent, is not usually necessary, and in some cases is not even possible. Normally one measures the variable under study at a number of distinct points in time during the interval, and in so doing faces the question: Does the data produced by "discrete time" measurement adequately index the change over time? The question may be divided into three parts: How frequently must measurements be made? What is the minimum number of measurements? How long must measurement continue?

The answers to these questions stem in part from the Sampling Theorem as employed in communications engineering. The Sampling Theorem is based on a mathematical technique for "decomposing" a signal into a number of components, each of which is a sine wave with the property that the sum of all such sine waves is equivalent to the original signal.[6] Theoretically, an exact decomposition may require an infinite number of such components, but if one is willing to accept a small margin of error, the number is finite and often small. For the purpose of determining how frequently measurements must be made on a signal, it is the component with the highest frequency (f) which is of primary interest. The Sampling Theorem reveals that a sequence of distinct or separate measurements

spaced at intervals which are less than or equal to one-half of the period (p) of this highest frequency component are sufficient to completely characterize or index a given signal (note that $p = 1/f$). In other words, measurements spaced at intervals (Δt), where $\Delta t \leq p/2$, produce data which fully index the change over time in a bounded interval.

As in the third paradigm in the prologue, then, it is possible to sample over time from an ongoing event in such a way that the "pauses" between measurements are "hardly noticeable," for the data contain information and can produce evidence for theoretical interpretations regarding the "complete" change over time which is involved. In addition to the question of how frequently measurements must be made, however, there is also the important and seldom asked question of the minimum number of measurements needed. In this case, the answer can be obtained by considering the number of data points needed to characterize the type of simple component sine wave mentioned above (see Arundale, 1971, pp. 148-149, for a fuller rationale). It can be shown that three measurements spaced at intervals of $\Delta t < p/2$ are sufficient to completely characterize a sine wave, assuming that the frequency (f) and hence the period ($p = 1/f$) of the signal are known. If the frequency is not known, three data points are an absolute minimum (because a third unknown is added), and the sine wave can be characterized in this case only if the measured values are all unequal (see Arundale, 1971, Appendix B, for this derivation; also Kendall, 1973, pp. 17-18). These considerations of the frequency and minimum number of measurements needed lead to the second of the three criteria. A design which fully indexes change over time must also involve:

> (2) Measurement at at least three points in time where:
> (a) the measurement interval Δt, is $\Delta t < p/2$, and p is the period of the highest frequency sinusoidal component of the signal, or:
> (b) the measured values, v_n, are unequal, $v_1 \neq v_2 \neq v_3$, and the frequency of the highest frequency sinusoidal component is unknown.

Before moving on to the third criterion, it is important to note two points

regarding the actual practice of sampling a continuous-state signal over time. First, it should be clear that the criterion above sets a minimum requirement: in most situations many more than three measurements would be required because the signal under study will have more than one sine wave component.[7] The issue of exactly how frequently to sample has not received much attention, other than the numerous explanations showing why $\Delta t \leq p/2$ is the appropriate value (Blackman and Tukey, 1958, pp. 54-55; Enochson and Otnes, 1968, pp. 18-20; Kendall, 1973, pp. 5-7; and Koopmans, 1974, pp. 309-311). Some authors have noted the problems associated with sampling rates that are "too slow" or "too fast," but have failed to provide specific advice (e.g., Blalock, 1969, p. 84; Holtzman, 1963, p. 200), and still others have failed to provide any direct consideration of the adequacy of data produced by sampling, despite excellent treatments of other issues in studying change over time (e.g., Gottman, 1973; Mayer and Arney, 1974). A second problem in the actual practice of sampling at equally spaced intervals of time has received considerable attention: the phenomenon of "aliasing" in which a high frequency signal appears or "masquerades" as a lower frequency signal, much as a strobe light appears to "slow" rapid movements (Blackman and Tukey, 1958, pp. 31-33; Enochson and Otnes, 1968, pp. 20-21). The problem is inevitable unless data are obtained at nonuniform sampling intervals, an issue which has begun to receive some limited attention (Freeman, 1965, pp. 77-89).

The one question remaining to be answered in developing the criteria is: How long must measurement continue? The Sampling Theorem and its related considerations again provide a response, in that they indicate that discrete measurements spaced at intervals, Δt, where $\Delta t \leq p/2$, will completely characterize a complex signal in a bounded interval. Specifically, if the bounded interval has a total time span, T, then the number of measurements needed to characterize it is $T/\Delta t = T/p/2 = 2fT$, since $f = 1/p$. Measurement must continue, then, until at least 2fT data have been collected, the only exception being if

the signal is periodic, or regularly repeats itself within the interval. In this case, measurement which continues over a subinterval equal to the period, P, of the lowest frequency component would be sufficient, or in other words, 2fP data would be required. Not surprisingly, the quantity 2fT (or 2fP) is also the number of independent data in any signal of duration T (Cherry, 1957, pp. 141-142). These considerations lead to the third criterion: a design which adequately indexes change over time must involve:

> (3) Measurement over the bounded interval, T, or over a sub-interval, P, where P is the period of the lowest frequency sinusoidal component of the signal.

These three criteria are the necessary and sufficient conditions which a research design must meet in order to index change over time. A design which meets these requirements will produce data which contain sufficient information, that given an appropriate analytic technique, one may gain evidence for a theoretical interpretation in terms of change over time, or process. Given that the criteria are minimum conditions, as noted, they impose fairly stringent requirements on research designs. But the criteria are also constructed to be as general as possible. Accordingly, the more information one has available in advance on the nature or form of the signal to be studied, the greater is the possibility of a "special case" in which one or more of the three criteria does not apply or may be modified. For example, if the continuous-state variable under study can take only one of a specific set of values (e.g., 0, 1.5, 3.0, 4.5, etc.), and one knows the smallest possible interval for which the event can be considered to remain in a single "state," then it may be possible to sample the ongoing event at a rate considerably less frequent than would be indicated by the second criterion. It is impossible to enumerate all possible special cases, but the principles involved stem directly from those commonly employed in the representation of time-varying signals (e.g., Koenig et al., 1967, pp. 20-25, 30-33; Milsum, 1966, Chs. 3 & 14).

Before turning to the implications of these three criteria for communication research, some consideration needs to be given to the value or appropriateness of an empirical test of the validity of the criteria. Of the three, 2(a) is the only one for which an empirical test could provide useful information. Criterion 1 is entirely definitional, and criteria 2(b) and 3 are straightforward mathematical extensions of the theory which underlies 2(a). An empirical test of criterion 2(a) would involve a study in which one first sampled a signal or signals using a range of different sampling intervals both above and below the criterion of $\Delta t \leq p/2$, and then determined whether or not the resulting data provided an adequate representation of the change over time in the original signal or signals.

Tick and Shaman conducted such a study in 1966 and confirmed that the sampling interval criterion was valid. The extensive theoretical and empirical work reported by Blackman and Tukey (1958) likewise supports the criterion. As Tick and Shaman point out, research which provides a direct test of the criterion is not common, and ordinarily one might be skeptical about accepting and applying such a highly general rule on the basis of only two studies. But even the briefest survey of the physical sciences and engineering disciplines, for example, will show that sampling of variables across time is very common in research, and that the sampling interval criterion is uniformly accepted as valid and seen as fundamental in achieving accurate results.

The weight of the evidence in favor of the criterion's validity is, indeed, very heavy, so that to provide an empirical test in the specific context of human communication research would provide no new information.[8] Such a study might serve to illustrate that sampling a communication variable at too long an interval misses significant information on change, and that sampling too frequently provides redundant and even obscuring information which must be eliminated to obtain accurate results. But here, too, an illustration of these effects

in the particular context of communication research would add little or nothing to the illustrations and more general theoretical discussions of too little or too much information which have already been provided by authors such as Blackman and Tukey (1958).

The Implications

In addition to providing criteria for indexing change over time, one purpose of this paper is to consider their implications for research design and measurement and for analysis techniques, in particular, and for the study of ongoing human communicative relationships, in general. The value of the three criteria with regard to research design is not only that they provide "standards" or guidelines for constructing designs which will adequately index change over time, but also that they provide a basis for assessing how well present and past designs have succeeded in indexing such change, if at all (see Arundale, 1971, pp. 156-164ff).

The first of the three criteria notes that an adequate design must involve both measurement of the variable(s) under study, and concurrent measurement of the points in time at which those measurements are made. This fundamental operation in the study of change over time is perhaps the easiest of the three criteria to meet, but is clearly not without its problems. Measurement of the time of observation is usually straightforward, though it may require an operational definition of the "observation point," e.g., the beginning, middle, or end of a measurement interval. On the other hand, measurement of the value of the variable under study is potentially fraught with difficulties in human communication research. If the instrument is "obtrusive," one must deal with the many problems of repeated measurement and its reactive effects--problems which have received some attention, but which need much more (e.g., Harris, 1963; Poor, 1973). If the measurement procedure is "unobtrusive" as in most forms of interaction analysis, some of these problems are avoided or reduced, but one may

not be able to index the desired variable, either because of the inherent nature of unobtrusive measures or because of the comparatively low level of development of such measures (e.g., Webb et al., 1966; see also Arundale, 1971, pp. 170-176).

The second criterion requires the researcher to consider a host of new issues in constructing research designs. To begin with, the criterion requires at least three and usually many more observation points in a design. Immediately most of the point and difference designs common in communication research are eliminated and one is left with the need to explore quite different "process" designs, or to create new ones (Arundale, 1971, pp. 164-170; Glass, et al., 1975), as well as with potential increases in numbers of subjects and expense. At the same time, however, these new designs also open new and powerful options, such as the possibility for in-depth study of one or a very few subjects over extended periods (Gottman, 1973; Gottman et al., 1969; and Glass et al., 1975; Holtzman, 1963).

Beyond the need to measure at several points, the second criterion focuses attention on the measurement interval, Δt, which must be such that $\Delta t \leq p/2$, where p is the period of the highest frequency component of the signal. The implication is that researchers must begin to consider certain characteristics of the form of the variation over time, in advance of the study. Ideally, one would be able to obtain such information through a Fourier analysis (Bergland, 1969) either of signals produced in earlier studies, or of well-known, general forms of variation, such as learning or diffusion curves. If such information does not exist, one may be able to determine some minimum response time for an event or a system which may serve as the basis for choosing a measurement interval. More generally, it may be possible to determine the frequency of the highest frequency component of a signal by examining characteristics of the event or system such as the "bandwidth" (Cherry, 1957, p. 303), the maximum "channel" or "input/output" rates (cf. Shannon, 1948), or the "filtering"

properties of the system (cf. Enochson and Otnes, 1968, Ch. 3; Koopmans, Chs. 4 & 6).

Despite the existence of alternatives for determining the appropriate sampling interval in advance, situations will still arise in which the researcher cannot obtain the necessary information. Here, the second criterion focuses attention on what may be termed the "resolution capability" of a research design. Specifically, if measurements are made at at least three points in time, and the measured values are unequal, $v_1 \neq v_2 \neq v_3$, then it is possible to determine the frequency of the highest frequency component which the design is capable of measuring or "resolving" ($f = 1/p = 1/2 \cdot \Delta t$, where Δt is the average measurement interval). While this approach is not a substitute for knowing the appropriate sampling interval in advance, it is valuable in assessing the limits within which either past or present designs have succeeded in indexing change over time. Considerations of the resolution capability of designs do not often appear in research on human communication, even though the resolving power of a design may place a constraint on the analysis of the data produced, and on the consequent theoretical interpretation.

The third of the three criteria notes that to fully index change over time, a design must involve measurement which continues throughout the interval of concern, or over a subinterval if the variation is periodic or cyclic. Like the first, this condition is fairly straightforward, but not without implications for research design. One might be able to reduce cost, for instance, by measuring over a subinterval. But like the second criterion, this advantage can be gained only if one knows the frequency or period of the lowest frequency component in advance (perhaps by Fourier analysis or by specific knowledge of the length of a cycle, as in small group studies). The third criterion also implies that researchers need to consider another factor in creating or evaluating designs -- the "inclusiveness" of the design. That is, whatever the length of the measurement period (whether T or P), a design is only capable of including

or indexing component frequencies with periods shorter than or equal to T or P, whichever is shorter. Considerations of a design's "inclusiveness" do appear in communication research, at present, as in comments on a design's strength or weakness in measuring a "long term effect." Such considerations constitute an important constraint both on analysis and on the theoretic interpretation of evidence, and should not be overlooked.

In addition to these implications for research design and measurement, the three criteria also have implications for analysis. Quite clearly, there are many different analytic techniques one can apply to any given set of data, and the choice one makes depends in large part on the nature of the design and on the evidence one needs for the theoretical interpretations one hopes to make. Assuming that one wishes to make interpretations in terms of change over time, the essential requirement in analysis is that the technique(s) employed "retain" the time dimension present in the data. Depending on the design, of course, almost any of the common inferential statistics can be an aid in producing evidence on change over time. Certain analytic techniques lend themselves more directly to providing evidence on change over time, however, and among these are several with potential value for analyzing continuous-state communication variables.[9] Time series or spectral analysis (Enochson and Otnes, 1968; Glass et al., 1975; Gottman et al., 1969; Granger and Hatanaka, 1964; Jenkins and Watts, 1968; Kendall, 1973; Koopmans, 1974, Ch. 9; and Mayer and Arney, 1974), Stochastic processes (i.e., continuous-state Markov processes), (Fararo, 1973, pp. 204-205), and Systems analysis (Cortes et al., 1974; Koenig et al., 1967; and Milsum, 1966), are perhaps of greatest value. Techniques such as repeated measures analysis of variance (Poor, 1973) and Path analysis (Duncan, 1975) may be useful, although time order is generally employed in path analysis with a different goal in mind (see Arundale, 1971, pp. 178-199 and 1972 for a review of other possible techniques, as well).

These analytic techniques are not as straightforward to learn or to use as the common inferential statistics, and it should be clear at this point that to apply them to any given set of data will not necessarily result in useful information on how communication events change over time. No analytic technique will produce valid evidence of change over time unless the data stem from a design which meets the criteria presented here.

Given the various implications for research design and measurement, as well as for analysis, one would be well justified in adding a further implication: it is just plain hard work to study ongoing human communicative relationships in a manner which indexes change over time. Perhaps for this reason, studies which index change over time in a manner in keeping with the criteria have not been frequent in research on human communication. Some examples do exist, however, in the work of Brooks and Scheidel (1968), Hovland et al. (1953, Ch. 8), and Insko (1964) on attitude change, in Goldman-Eisler's (1968, Chs. 6 & 7) work on pauses, and in Kivlin et al.'s (1968) work on diffusion. Analytic techniques such as those mentioned have been productively applied in neighboring disciplines such as psychology, and the work of Glass et al., (1975) and Gottman et al., (1969) on time series studies, of Gottman (1973) and Holtzman (1967) on studies of the single case, and of Levin and Lord (1975) on speech pitch and emotion all provide valuable models and ideas for communication researchers. Other studies might well be included, and a more complete summary may be found in Arundale (1971, pp. 62-69).

Epilogue

Beyond the more particular implications for research which have been considered thus far, the three criteria suggest other implications which apply more generally to the study of ongoing human communicative relationships. One fairly straightforward implication is that to advance the state of human communication theory, especially with respect to change over time, researchers will have to

explore and adopt new techniques which assure that the data their studies produce will contain the kind of information needed for theoretical interpretations in terms of change over time (or process in its narrow sense). And this comment implies the reverse, as well: If researchers do not employ techniques which satisfy the three criteria, they will have to either avoid theoretical interpretations in terms of change over time, or recognize explicitly that such interpretations are not supported by evidence stemming from information contained in the data.

The general implication that researchers must explore and adopt new research techniques which will index change over time is not to be taken as a suggestion that such techniques are better than current ones, or should replace them. Rather, the implication is that a number of additions to current research techniques are needed, the selection and development of which may be guided in part by these criteria. A great deal has been and will be learned about human communication utilizing techniques resembling those in the first two paradigms of the prologue, i.e., point and difference designs. Not all studies need to utilize the third paradigm, i.e., change over time or "process" designs, and the criteria should help researchers recognize more clearly which studies must index change over time and which need not.

That communication researchers will have to add techniques such as those suggested should also not be taken to imply that these techniques are the only ones to be added. Indexing change over time is crucial in studying ongoing human communicative relationships, but it is just as important that the data contain the additional information which Krippendorff (1970) has argued is requisite in adequate "communication data." Likewise, it should be clear that indexing change over time is a necessary, but not sufficient step in adopting a general systems approach in studying human communication. To utilize either a systems approach, or the long advocated "process approach," requires one to

generate data containing information not only on change over time, but also on interaction, emergence, and on many of the other concepts central to theoretical interpretations in a systems framework.

Criteria for indexing change over time are therefore one element in the larger picture of studying ongoing human communicative relationships. They do not present an easy solution, or a way to avoid effort. They do provide a way to gain access to a large and important class of information which is not now fully available--information on how communication behaviors develop, evolve, interrelate, and terminate during an ongoing event, or in short, on how they change over time.

One parting shot. Imagine for a moment that instead of becoming less like the physical and engineering sciences, as has been argued (e.g., Smith, 1972, passim), communication researchers became more like their counterparts in these other ivory towers. More like them in the sense of examining and modifying some of their multitude of research techniques. And more like them in that these counterparts do not often see their research in terms of the "traditional" hypothetico-deductive paradigm, nor as depending on the "standard" point and difference designs for valid results. Instead, they see their research in a framework very close to the systems paradigm described by Meehan (1968) and Monge (1973), and depend heavily on designs much like the "process" designs considered here. In doing so, they have made considerable advances in dealing with complex, dynamic systems--systems which are ultimately less complex than human communication systems, but which are closer to having viable theoretical explanations in systems terms. There is no panacea in looking to these other sciences, only the possibility of flashes of insight. And we will not be able to equip our ivory towers with all of the imaginary equipment of the prologue, for only some of the research techniques will be of use. But then, our goal is not to gain techniques, only to find a window on the process of human communication.

FOOTNOTES

[1]It is instructive that process or change over time is sufficiently basic in Bertalanffy and Laszlo that it has the character of an unstated assumption or axiom, which only on occasion surfaces in explicit recognition, The same phenomenon obtains throughout the physical and engineering sciences, where time is also a fundamental dimension.

[2]Note that the term "change" is frequently used to refer to what is termed "difference" in this paper, i.e., the "change" which appears between two points in time (e.g., Coleman, 1968; Harris, 1963). "Difference" is the minimal form of "change over time," although as will be suggested later, difference designs are capable only in special cases of producing data and evidence which may be interpreted in terms of "change over time" or "process," as these terms are used here. It should be noted at this point that the typical cross-sectional study gathers data at a single point in time, and may be designed to tap a number of different populations which are, at the moment of measurement, at different stages in some development or "change" over time. The resulting data, if arranged along a time axis relative to some reference time, will appear similar to the data gathered using a "process" design. Despite the similarity in form, however, these two types of data contain different information (Coleman, 1968, p. 475), and the problems inherent in the use of cross-sectional data to study developmental change have been dealt with at length in Baltes (1968) and Schaie (1965).

[3]There are apparently a number of reasons why researchers studying human communication have not made more use of designs in this third category (Arundale, 1971, pp. 71-74). Coleman (1968) suggests that one reason may be that "... the concept of change is a second-order abstraction. It is based on a comparison, or difference between two sense impressions, and, simultaneously, a comaprison of the times at which the sense impressions occurred. Thus the concept of change requires an extra intellectual leap beyond the mere formation of concepts which reflect the state of the world. Historically, it had to also wait upon a systematic concept of time, for observation of differences in time have always to run alongside the observations of differences in the state for which change is of interest (pp. 428-429)."

[4]Note that in no case is time considered here (or in communications engineering) as a "causal" variable. Time is a "reference" variable in both cases which allows one to describe change in some other variable of interest. In this sense, "time" does not cause "aging," rather, the process of aging (which is referenced to time) is caused by tissue deterioration, etc. (processes which are also time-referenced).

[5]Such a restriction to a bounded interval is necessary in this case, though it may not be sufficient. It may also be necessary to further subdivide the interval to obtain segments within which the signal is "locally" or "quasi-" stationary (see Hamming, 1962, pp. 77-78; Keast, 1967, p. 15). It appears that such an approach would work for many or most variables of concern to the researcher in human communication, given that one could not assume a "weak stationarity" (Enochson and Otnes, 1968, pp. 229-232; Koopmans, 1974, passim, esp. p. 317). While the problem of non-stationarity is too complex to treat fully, here, considerable progress has been made in dealing with such signals (see Davis, 1952; Enochson and Otnes, 1968, Ch. 9; Granger and Hatanaka, 1964; Krut' ko, 1969).

[6]Note that this additive property applies only to the mathematical decomposition of a single signal and is part of the mathematical formulation (Fourier analysis). No assumption is made or is necessary regarding additivity in the communication event or system from which the variable or signal stems, nor is there any requirement that any set or subset of several variables or signals be additive. Finally, note that there is no suggestion here that such mathematical decomposition via Fourier analysis is, in and of itself, a useful analytic technique in human communication research. For more information on Fourier analysis and the Sampling Theorem, see Bergland, 1969, pp. 41-52; Blackman and Tukey, 1958; Bracewell, 1965; Cherry, 1957, pp. 128-143; Enochson and Otnes, 1968, Ch. 1; Hamming, 1962, Ch. 6; and Keast, 1967, Ch. 2.

[7]It is important to note that on completely different grounds, Coleman (1968, p. 453-456) has also suggested that three or more observations of the same event are a requirement for separating random measurement error from true change.

[8]The author's own study of the effects of sampling at different intervals from a simulated continuous-state communication variable was parallel in many respects to the approach taken by Tick and Shaman (1966). The results were so entirely consistent with the published results of these and other authors as to be not worth reporting.

[9]Note again the restriction to continuous state variables. Other techniques are available for studying change over time in discrete-state variables, and such studies are increasingly being reported in the communication research literature. At the moment, however, there exist no clear criteria for determining whether or not discrete-state data adequately index change over time.

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